WHITE PAPER

TD-LTE

Exciting Alternative, Global Momentum

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Executive Summary

Spectrum, the single most important resource for telecommunication voice and mobile broadband service, is finite and limited. As subscribers demand faster and increased capacity anytime, anywhere, operators face the challenge of maximizing all available spectrum assets – FDD or TDD.

In previous 3GPP standards, mobile operators have deployed Frequency Division Duplex (FDD) technology and the expectation was the same for LTE. However, in designing LTE, 3GPP committed to the first truly global technology standard by ensuring it supported not only FDD, but also Time Division Duplex (TDD) spectrum.

To open the LTE ecosystem to FDD and TDD operation, the 3GPP standard has identified fifteen paired FDD and eight unpaired TDD spectrum bands. This allows an operator to introduce LTE in previously unattractive TDD spectrum bands, as well as in previously unavailable spectrum bands.

A key advantage of the LTE ecosystem is the vast economy of scale gained through combining LTE FDD and TDD (TD-LTE) in a standardized way. The 3GPP standard allows both devices and implementations to be simpler, a major factor in reducing cost for deploying a mobile broadband technology. Since other TDD based technologies, including TD-SDMA and WiMAX, also have a migration path to LTE, combining FDD and TDD makes the scale and economy of the LTE ecosystem especially robust and attractive.

This paper addresses TD-LTE's physical layer, performance, applicable spectrum, differences from FDD and its global momentum, while answering questions operators, regulators, license holders and investors may have about the technology.

Clearly no single technology will solve the growing mobile broadband demand. Operators will need to use all the spectrum they can secure. In TD-LTE, operators have a very intriguing alternative, with global momentum, that matches its FDD counterpart.

Mobile Broadband

Intriguing Alternative Solution

Today most operators are running their networks and spectrum at full capacity, trying to meet the ever increasing mobile data demand. Monthly data consumption in 2010 is already topping 5GB per month. Since penetration of smartphone devices – a key driver for data growth – is still below 20% worldwide, operators expect the growth to continue.

To address this growing mobile broadband demand, the 3GPP standards body released the next technological step, Long Term Evolution (LTE). LTE is designed to substantially improve end-user throughputs, increase sector capacity and reduce user plane latency. It is a simple and flat network architecture that delivers a significantly improved user experience with full mobility, resulting in low operating costs for operators.

LTE is the logical next step for over four billion subscribers on 3GPP networks. Already over 100 global operators are committed to deploying LTE and have commenced technical evaluation and trials. FDD LTE, which uses a paired spectrum, one for uplink and the other for downlink, is the traditional modulation used by 3GPP operators and gained an early lead in LTE deployments.

TD-LTE uses a different approach, a single frequency sharing the channel between transmission and reception, spacing them apart by multiplexing the two signals on a real time basis. While FDD transmissions require a guard band between the transmitter and receiver frequencies, TDD schemes require a guard time or guard interval between transmission and reception. The time must be sufficient to allow the signal traveling from remote transmitters to arrive before a transmission is started and the receiver inhibited.

Typically more data travels in the downlink direction of a cellular telecommunications system, suggesting that the capacity should be greater in the downlink direction. TD-LTE systems make this possible by changing the number of time slots allocated to each direction. Often this is dynamically configurable, so it can be altered to match the demand. Another characteristic of TD-LTE transmissions is the aspect of latency. Due to the time multiplexing between transmit and receive, there can be a small delay between the data being generated and it being actually transmitted. However in a datacentric environment such as LTE, this delay is hardly noticeable.

Global Momentum

TDD LTE, also known as TD-LTE, was adopted as the evolution of choice for TD-SCDMA, China's 3G standard. Despite being tapped by the world's largest mobile operator, TD-SCDMA was not universally embraced, due to a lack of available devices, early technical challenges and its failure to move away from the shadows of WCDMA.

TD-LTE has received industry ratification and has successfully passed the proof of concepts tests for LTE/SAE by the 3GPP, the NGMN3GPP and NGMN. The specifications have now been submitted to the International Telecommunication Union (ITU) for approval as a 4G standard.

While China Mobile can rightfully be tagged as the primary operator driving TD-LTE, the technology clearly has global momentum behind it now, attracting attention to TDD spectrum. China Mobile with its half a billion subscribers can clearly define a market segment on its own. However, it is the interest from other major markets – such as Russia, Japan, India and the US – that has put TD-LTE on every operator's plan.

Softbank in Japan recently committed to trials of TD-LTE in the 2.5GHz spectrum band to which it gained access after acquiring a stake in Willcom. Japan is currently one of the early adopters of LTE with both NTT DoCoMo and KDDI already committed to launching the FDD version in 2010 and 2011 respectively. In the US, Clearwire, a leading WiMAX operator in a unique position of having enough spectrum to support multiple technologies, has indicated an interest in LTE. Clearwire, along with some vendors, has applied to the 3GPP to include the 2496MHz to 2690MHz frequency band in the US for TD-LTE, extending the potential addressable market.

Russia's state telecom giant Svyazinvest has already chosen TD-LTE has its 4th generation mobile technology. Proposed nationwide coverage of Russia clearly presents another key driver for the TDD flavor of LTE. In the just concluded spectrum auctions in India, one of the key talking points was what technology the various winners would adopt for the TDD spectrum made available for broadband access. Qualcomm, one of the key winners, stated before the auction that it was going to deploy TD-LTE. Though the decision from the other key winners has yet to be announced, the continued WiMAX to LTE story can only point to potential TD-LTE networks at some point in time.

Europe's major operators have typically deployed FDD networks, but recent indications of winners in the German auctions indicates that operators are increasingly interested in TDD bands. TD-LTE makes those bands an attractive asset with a more realistic price and the ability to deliver similar performance and coverage to the FDD version. Other ongoing spectrum activity is the application to the 3GPP to include the 3.5GHz band profile for TD-LTE. Also chipsets are expected to support both TDD and FDD LTE on the same chip, ensuring roaming between the two bands

Spectrum

Among the frequency bands in the world that are likely candidates for LTE deployments are the cellular, PCS, AWS and digital dividend bands. It is expected that the FDD paired spectrum bands will be the most common spectrum blocks. However with TD-LTE as a committed 3GPP standard, there are spectrum blocks available that could be used in an unpaired approach. This makes the use of TD-LTE much more likely. TDD spectrum bands allocated in most parts of the world today are part of a technology agnostic approach.

Many countries throughout the world have large chunks of unpaired TDD spectrum available, both used and unused. History also suggests that unpaired spectrum will trade at a much lower price per MHz/population than its FDD equivalent. Table 1 below highlights the key TDD bands, with the most likely bands being the 2.3GHz and 2.6GHz. Recently operators and vendors have requested the inclusion of a new band to support TD-LTE in North America.

Table 1. 3GPP LTE TDD Spectrum Bands

Band	Identifier	Frequencies (MHz)
33,34	TDD 2000	1900 -1920 2010- 2025
35,36	TDD 1900	1850 – 1910 1930 – 1990
37	PCS Center Gap	(1915) 1910 – 1930
38	IMT Extension Center Gap	2570 – 2620
39	China TDD	1880 – 1920
40	China TDD	2300 – 2400
Newly Proposed	US TD-LTE	2496 – 2690

TD-LTE

The 3GPP aimed to develop a 4G technology which is truly global and one which offers operators the most flexibility. In designing LTE, it agreed for the first time to have a common radio interface specification for both TDD and FDD, in effect using the same solutions for FDD and TDD, driving a burgeoning ecosystem and economies of scale. 3GPP has successfully fulfilled its goal to achieve a single radio-access specification equally applicable to paired and unpaired spectrum, with TD-LTE offering similar capacity, coverage and user experience to FDD LTE. From a technical specification perspective, few significant differences exist between FDD and TDD on the physical layer and, in particular, with the frame structure. On the higher layers, the differences are limited to configurability of the physical layer and negligible timing relations due to the discontinuous nature of uplink and downlink.

TD-LTE and LTE FDD Differences

In LTE, the differences between TDD and FDD are solely a physical layer manifestation and therefore invisible to higher layers. As a result, there are no operational differences between the two modes in the system architecture.

At the physical layer, the fundamental design goal is to achieve as much commonality between the two modes as possible. The key design differences between the two stem from the need to support various TDD UL/DL allocations and provide coexistence with other TDD systems. In this regard, several additional features are exclusive only to TD-LTE. Table 2 provides an overview of these physical layer features.

**Table 2.
TDD Exclusive Features**

Feature	TDD Implementation
Frame structure	Introduction of a special subframe for switching from DL to UL and to provide coexistence with other TDD systems
Random access	Additional short random access format available in special subframe, multiple random access channels in a subframe
Scheduling	Multi-subframe scheduling for uplink
ACK/NACK	Bundling of acknowledgements or multiple acknowledgements on uplink control channel
H-ARQ process number	Variable number of H-ARQ processes depending on the UL/DL allocation

FDD and TDD modes also differ in the time placement of the synchronization signals. In FDD, the primary and secondary synchronization signals are contiguously placed within one subframe, while TD-LTE places the two signals in different subframes, separated by two OFDM symbols. However, this separation of primary and secondary signals does not affect the performance of synchronization channels compared to LTE FDD. System simulations also shows that the sector throughput and 5 percentile edge throughput performance of both TD-LTE and FD-LTE are quite similar for best effort traffic when comparing a 10+10 MHz FDD to 20 MHz

TDD. The TD-LTE system spectral efficiency will be slightly degraded because of the additional overhead due to GAP period. Another benefit of TD-LTE is the flexibility it offers operators in adjusting the DL/UL ratio. This feature allows operators to configure the DL/UL ratio to suit the traffic ratio on their network. Figure 1 below illustrates how this potential configuration impacts performance, highlighting how TD-LTE's spectral efficiency ensures maximization of available bandwidth.

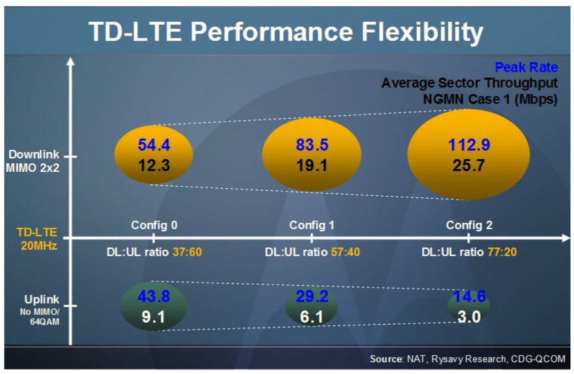

Figure 1. TD-LTE Performance Flexibility

TD-LTE Coverage

A common perception among the industry regarding TD-LTE is that TD-LTE does not match LTE FDD for coverage. Link budgets analysis for both outdoor and indoor environments, with the same system configuration, transmitter and receiver settings, shows that TD-LTE matches its FDD counterpart in terms of "raw" coverage. In effect, TD-LTE and FDD LTE utilize the same 1ms frame resource block hence the same amount of power (200mW) will be transmitted during the same amount of time in both TDD or FDD, meaning the footprint will be exactly the same.

What has been fuelling this perception of a lower coverage for TD-LTE network is the edge of cell link budget single user (unloaded network) data rate where a FDD-LTE system will show a UL edge of cell performance twice that of TD-LTE. Link Budget calculation focuses only on the edge of cell single user performance when that user device is at the maximum limit of its uplink power, hence can only be given access to five resource blocks (one resource block every 1ms for 5ms or 1/2 the length of the 10ms LTE frame in the case of a 50:50 DL/UL ratio TD-LTE network) to meet the 200mW max power requirement. In comparison, on a FDD-LTE system, at the edge of cell, one single device will be able to send 200mW continuously for 10ms (scheduler can give device access to 10 resource blocks of 1ms with no waiting time) – as represented in Figure 2.

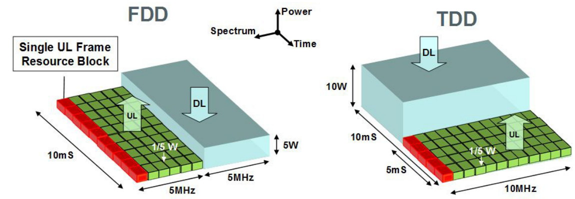

Figure 2. Illustration of a single user at the edge of cell on an empty FDD LTE and TD-LTE network

However in a commercial environment where the cells have more than 1 user, the performance of FDD and TD-LTE, as demonstrated with 5 percentile edge throughput performance, will be very similar as the FDD device will not be able to access the full frame 10 UL resource blocks like he did on an unloaded single user network. In that case, because the TD-LTE channel is twice as wide as the FDD channel (during transmit & receive times that is) the subscriber is likely to be given access to as many resource blocks as an FDD system despite the half UL time in the frame compared to a FDD frame as illustrated in Figure 3 below.

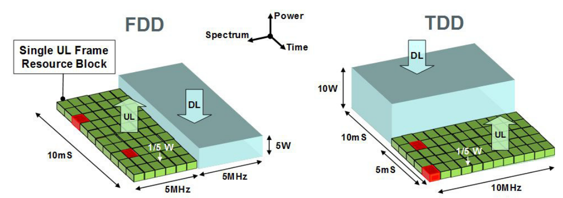

Figure 3. Illustration of multiple users at the edge of cell on a loaded FDD and TDD network

For operators, TD-LTE will provide the exact same coverage and very similar sector throughput than a FDD-LTE system all the way to the edge of cell except when only 1 subscriber is on the network, which is indeed a very unlikely occurrence. TD-LTE with its adaptable DL: UL ratio means it allows for an optimized and efficient use of the uplink and downlink bandwidth as the operators is able to more closely match the asymmetry of today data traffic (Internet, Video, etc) and maximize spectrum usage and efficiency in almost all scenarios.

Frame Structure

Each radio frame spans 10ms and consists of ten 1ms subframes. Subframes 0 and 5 contain synchronization signal and broadcast information necessary for the User Equipment (UE) to perform synchronization and obtain relevant system information, making them downlink subframes.

Subframe 1 is a special subframe that serves as a switching point between downlink to uplink transmission. It contains three fields – Downlink Pilot Time Slot (DwPTS), Guard Period (GP) and Uplink Pilot Time Slot (UpPTS). To address the switching from uplink to downlink transmission, no special subframe is provisioned, but the GP includes the sum of switching times from DL to UL and UL to DL. The switching from UL to DL is achieved by appropriate timing advance at the UE.

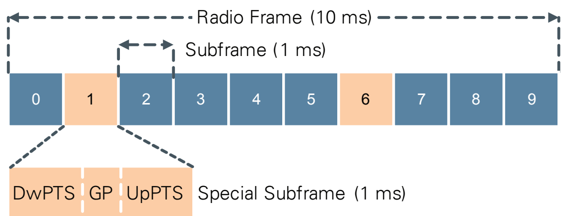

Figure 4. TDD frame structure.

Two switching point periodicities are supported – 5ms and 10ms. For the 5ms switching point periodicity, subframe 6 is likewise a special subframe identical to subframe 1. For the 10ms switching point periodicity, subframe 6 is a regular downlink subframe. Table 3 on next page illustrates the possible UL/DL allocations.

Table 3.
Uplink-Downlink Allocations

UL/DL Configuration	Period (ms)	Subframe									
		0	1	2	3	4	5	6	7	8	9
0		D	S	U	U	U	D	S	U	U	U
1	5	D	S	U	U	D	D	S	U	U	D
2		D	S	U	D	D	D	S	U	D	D
3		D	S	U	U	U	D	D	D	D	D
4	10	D	S	U	U	D	D	D	D	D	D
5		D	S	U	D	D	D	D	D	D	D
6	5	D	S	U	U	U	D	S	U	U	D

As shown in Figure 4, the total length of DwPTS, GP, and UpPTS fields is 1ms. However, within the special subframe, the length of each field may vary depending on co-existence requirements with legacy TDD systems and supported cell size.

Table 3 above provides the supported configurations where the length of each field is given in multiples of OFDM symbols. Note that this assumes that the eNodeB (base station in UMTS terminology) and UE switching time are less than the duration of an OFDM symbol with extended cyclic prefix (CP).

Table 4.
DwPTS/GP/UpPTS length (OFDM symbols)

Format	Normal CP			Extended CP		
	DwPTS	GP	UpPTS	DwPTS	GP	UpPTS
0	3	10		3	8	1
1	9	4		8	3	
2	10	3	1	9	2	
3	11	2		10	1	
4	12	1		3	7	2
5	3	9		8	2	
6	9	3	2	9	1	
7	10	2		-	-	-
8	11	1		-	-	-

An example of coexistence with legacy UMTS Low Chip-Rate (LCR) TDD system is shown in Figure 5, which illustrates switching point alignment between the two systems.

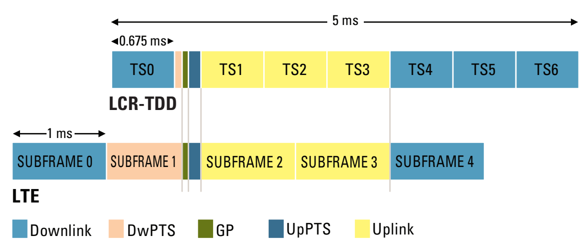

Figure 5. Coexistence with LCR-TDD UMTS system.

Obviously, to minimize the number of special subframe patterns to be supported, not all legacy TDD configurations can be supported. For LCR-TDD configurations, Table 4 demonstrates co-existence with the 5DL:2UL and 4DL:3UL LCR-TDD splits, which are generally viewed as the most common deployment configurations.

A. Downlink Pilot Time Slot

The central design philosophy is to treat the DwPTS as a regular but shortened downlink subframe. As a result, it always contains reference signals and control information like a regular downlink subframe, and may carry data transmission at the discretion of the scheduler. In addition, it also contains the primary synchronization signal (PSS) used for downlink synchronization. An illustration of the DwPTS structure is shown in Figure 6.

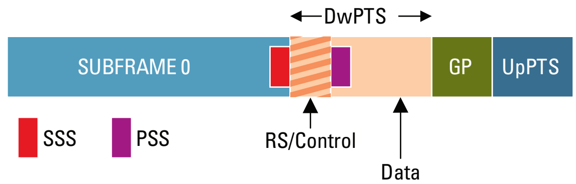

Figure 6. DwPTS Structure

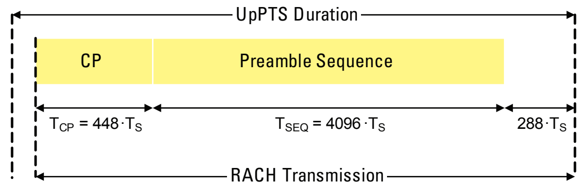

Figure 7. RACH in UpPTS.

Figure 6 shows the secondary synchronization signal (SSS) being transmitted on the last symbol of subframe 0. The PSS is transmitted on the third OFDM symbol in DwPTS to allow the same reference signal placement in the DwPTS as in other downlink subframes. This, however, will result in small degradation of cell search performance using coherence detection at very high vehicular speed due to channel variations.

In Table 4, the majority of configurations allocate at least eight OFDM symbols to the DwPTS. That means data transmission capacity is generally similar to a regular downlink subframe. When there are only three OFDM symbols allocated to DwPTS, data transmission should still be possible at the discretion of the eNodeB so as not to waste spectrum resources, especially at high system bandwidth.

B. Uplink Pilot Time Slot

From Table 4, it is clear that there are only two values for UpPTS duration (one or two OFDM symbols). As a result, UpPTS usage by the UE is limited to either sounding reference signals or random access (RACH) transmission. Random access requires UpPTS length of two OFDM symbols. When one OFDM symbol is allocated to the UpPTS, only sounding reference signals transmission is possible.

Random access on the UpPTS is limited by the length of the UpPTS and therefore not applicable to all deployment scenarios. An illustration of the random access transmission in the UpPTS is shown in Figure 7.

Random access begins at 4832×Ts seconds, where Ts = 1/(15000×2048), before the end of the UpPTS with a duration of 4544×Ts seconds. This leaves a guard period of 288×Ts seconds, allowing for a maximum supported cell size of approximately 1.4 km. For larger cell sizes, RACH will have to be supported in regular uplink subframes to provide a sufficient guard period.

Within each random access region, 64 preambles are available for use. Studies show that the signal-to-noise requirement for this RACH format is approximately -9.5 and -1.8dB under AWGN and Typical Urban channels, respectively.7 These required operating points are relatively high and therefore this format can only be supported in cells with high signal-to-noise ratios.

C. Guard Period

The guard period denotes the switching point between downlink and uplink transmission and its length determines the maximum supportable cell size. For LTE, cell size of up to 100 km must be supported, requiring a guard period of approximately 666.7ms. This is possible by choosing Format 0 in Table 4 for the special subframe.

TD-LTE System Design

In order to support numerous UL/DL allocations, TDD design allows for greater flexibility and robustness. This section describes design challenges inherent to TD-LTE operation and summarizes concepts and solutions employed in LTE.

A. Downlink Control Design

In LTE, downlink control signaling serves three main purposes that must be further addressed in TDD:

1. Indicate the size of the control region
2. Provide downlink ACK/NACK
3. Provide signaling related to scheduling assignments and power control.

One important design criteria was to ensure that the maximum size of the downlink control region for FDD (3 OFDM symbols per subframe) is large enough to provide all the control signaling needed for the different downlink-uplink TDD allocations. For the uplink-asymmetric allocation, each control region must address several uplink subframes in addition to its own downlink subframe. However, by utilizing several control overhead reduction techniques, it is expected that the current design will be sufficient. For instance, scheduling grant addressing may span up to two uplink sub-frames using a 2-bit sub-frame indicator. In coverage-limited scenarios, uplink users can be scheduled aggressively and then rely on non-adaptive HARQ re-transmissions, which do not require additional grants.

Naturally, timing of the downlink acknowledgement is variable based on the UL/DL configuration. For PUSCH transmissions in subframe n, Node-B will transmit the acknowledgment in subframe n+k, where k is given in Table 5. This allows for at least 3ms processing time at the Node-B.

Table 5.
Downlink ACK/NACK timing index *k* for TDD

TDD UL/DL Configuration	subframe index *n*									
	0	1	2	3	4	5	6	7	8	9
0	-	-	4	7	6	-	-	4	7	6
1	-	-	4	6	-	-	-	4	6	-
2	-	-	6	-	-	-	-	6	-	-
3	-	-	6	6	6	-	-	-	-	-
4	-	-	6	6	-	-	-	-	-	-
5	-	-	6	-	-	-	-	-	-	-
6	-	-	4	6	6	-	-	4	7	-

Finally, an issue related to multi-subframe scheduling in the uplink is how to transmit multiple acknowledgements in one downlink subframe. Here, the solution is to associate a data transmission in an uplink subframe with a corresponding downlink subframe and PHICH group. This will allow a UE to implicitly determine where its acknowledgements will be transmitted.

B. Uplink Control Design

In the uplink, the main issue with TDD operation is the need to transmit several acknowledgements on the same subframe. This is because in most cases, the TDD split is asymmetrical in favor of the downlink. From a timing perspective, the UE will upon detection of a data transmission in subframe n, transmit the acknowledgement in uplink subframe n+k, where k is given in Table 6. This allows for at least 3ms processing time at the UE. Note that, in many cases, the UE will have to transmit multiple acknowledgments in one uplink subframe. For instance, with 2UL:2DL+DwPTS configuration, some uplink subframes must carry acknowledgements for two downlink subframes as shown in Figure 8. In this case, the UE must aggregate all the acknowledgements and transmit only on one uplink channel in order to preserve single-carrier property.

Table 6.
Uplink ACK/NACK timing index *k* for TDD

TDD UL/DL Configuration	subframe index *n*									
	0	1	2	3	4	5	6	7	8	9
0	4	6	-	-	-	4	6	-	-	-
1	7	6	-	-	4	7	6	-	-	4
2	7	6	-	4	8	7	6	-	4	8
3	4	11	-	-	-	7	6	6	5	5
4	12	11	-	-	8	7	7	6	5	4
5	12	11	-	9	8	7	6	5	4	13
6	7	7	-	-	-	7	7	-	-	5

For UEs with good coverage, there should be no issue in transmitting multiple acknowledgments in order to allow individual feedback for each H-ARQ process. PUCCH resource selection is used to convey the multiple acknowledgements. As an example, two PUCCH resources can be reserved and by selecting the appropriate resource together with QPSK modulation, the UE is able to transmit six different acknowledgement combinations.

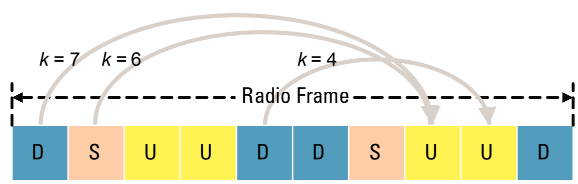

Figure 8. Example of uplink acknowledgement association.

On the other hand, UEs in coverage-limited situation may encounter difficulties in transmitting multiple acknowledgements. As a result, acknowledgement bundling (AND of all acknowledgements) can be used. This can significantly increase uplink coverage, so UEs that are in poor coverage may be configured to operate in this mode. However, with bundling of acknowledgements, UE may transmit erroneous acknowledgement if some downlink assignment grants are missed. To solve this problem, information about the number of grants to be transmitted to a UE within the bundling window is included. The UE can then determine whether any grant was missed and, if so, will not transmit any acknowledgement (i.e. DTX).

In the uplink, ACK/NACK resource indication will be implicitly tied to the downlink control channel used for scheduling assignment. For TD-LTE, the UE may receive several assignments in different DL subframes within the same ACK/NACK response window (see Figure 8 for instance) and thus the implicit relationship also includes the appropriate downlink subframe index number.

C. H-ARQ Process Number

In LTE, N-channel stop and wait H-ARQ protocol is employed where the value of N depends on processing times at the Node-B and UE, as well as propagation time at the UE. Using processing time of 3ms at the Node-B and UE, the maximum number of H-ARQ processes for the supported UL/DL formats is given in Table 7.

Table 7.
Maximum number of H-ARQ processes

TDD UL/DL Configuration	Process Number	
	DL	UL
0	4	7
1	7	4
2	10	2
3	9	3
4	12	2
5	15	1
6	6	6

Note that synchronous H-ARQ is used in the uplink, while asynchronous H-ARQ is used in the downlink.

Performance Results

Simulations were performed to analyze system performance using parameters outlined in Table 11. Table 8 presents the system IMT-A simulation cases of interest. In our analysis, DwPTS/GP/UpPTS lengths as given by Format 3 of Table 4 are used. In this format, eleven OFDM symbols are available in DwPTS. Thus, the DwPTS field may be considered as a slightly shortened downlink subframe. The results shown assume the maximum amount of control overhead (three OFDM symbols) in each downlink subframe, although the PDCCH was not explicitly modeled.

Table 8.
System Simulation Scenario

	Simulation Case
IMT-A	Indoor hotspot (InH)
	Urban micro-cell (UMi)
	Urban macro-cell (UMa)
	Rural macro-cell (RMa)

System data throughput is analyzed using full buffer file transfer model. The system bandwidth is 10 MHz shared between downlink and uplink transmission. The chosen UL/DL allocation is TDD Configuration 1 4UL:4DL+2DwPTS. Table 9 illustrates the sector and user spectral efficiency of TD-LTE in the downlink for IMT-A simulation scenarios.

Table 9.
DL spectral efficiency

Case		TDD Config 1	
		2x2 (SU-MIMO)	4x2 (SU-MIMO)
InH	Cell spectral efficiency (bps/Hz/cell)	4.420	-
	Cell edge user spectral efficiency (bps/hz)	0.158	-
UMi	Cell spectral efficiency (bps/Hz/cell)	2.070	2.470
	Cell edge user spectral efficiency (bps/hz)	0.062	0.073
UMa	Cell spectral efficiency (bps/Hz/cell)	1.090	1.480
	Cell edge user spectral efficiency (bps/hz)	0.020	0.030
RMa	Cell spectral efficiency (bps/Hz/cell)	1.380	1.780
	Cell edge user spectral efficiency (bps/hz)	0.029	0.042

Likewise, Table 10 illustrates the sector and user spectral efficiency of TD-LTE in the uplink.

Table 10.
UL spectral efficiency

Case		TDD Config 1	
		1x4 (SIMO)	1x8 (SIMO)
InH	Cell spectral efficiency (bps/Hz/cell)	2.941	3.351
	Cell edge user spectral efficiency (bps/hz)	0.199	0.243
UMi	Cell spectral efficiency (bps/Hz/cell)	2.044	2.587
	Cell edge user spectral efficiency (bps/hz)	0.059	0.073
UMa	Cell spectral efficiency (bps/Hz/cell)	1.553	2.062
	Cell edge user spectral efficiency (bps/hz)	0.062	0.085
RMa	Cell spectral efficiency (bps/Hz/cell)	1.638	2.150
	Cell edge user spectral efficiency (bps/hz)	0.056	0.074

For full-buffer traffic, the spectral efficiency for TD-LTE systems is similar to that of FDD except for a slight loss resulting from the use of the special subframe. The performance of other MIMO modes for DL and UL will be provided in the next update of this paper.

Table 11. System simulation parameters				
Deployment scenario for the evaluation process	Indoor hotspot (InH)	Urban micro-cell (UMi)	Urban macro-cell (UMa)	Rural macro-cell (RMa)
Layout	Indoor floor	Hexagonal grid	Hexagonal grid	Hexagonal grid
Inter-site distance	60 m	200 m	500 m	1 732 m
Channel model	Indoor hotspot model (InH)	Urban micro model (UMi)	Urban macro model (UMa)	Rural macro model (RMa)
User distribution	Randomly and uniformly distributed over area	Randomly and uniformly distributed over area. 50% users outdoor (pedestrian users) and 50% of users indoors	Randomly and uniformly distributed over area. 100% of users outdoors in vehicles	Randomly and uniformly distributed over area. 100% of users outdoors in high speed vehicles
User mobility model	Fixed and identical speed |v| of all UTs, randomly and uniformly distributed direction	Fixed and identical speed |v| of all UTs, randomly and uniformly distributed direction	Fixed and identical speed |v| of all UTs, randomly and uniformly distributed direction	Fixed and identical speed |v| of all UTs, randomly and uniformly distributed direction
UT speeds of interest	3 km/h	3 km/h	30 km/h	120 km/h
BS noise figure	5 dB	5 dB	5 dB	5 dB
UT noise figure	7 dB	7 dB	7 dB	7 dB
BS antenna gain (boresight)	0 dBi	17 dBi	17 dBi	17 dBi
UT antenna gain	0 dBi	0 dBi	0 dBi	0 dBi
Thermal noise level	–174 dBm/Hz	–174 dBm/Hz	–174 dBm/Hz	–174 dBm/Hz
Base station (BS) antenna height	6 m, mounted on ceiling	10 m, below rooftop	25 m, above rooftop	35 m, above rooftop
Number of BS antenna elements	Up to 8 rx Up to 8 tx	Up to 8 rx Up to 8 tx	Up to 8 rx Up to 8 tx	Up to 8 rx Up to 8 tx
Total BS transmit power	24 dBm for 40 MHz, 21 dBm for 20 MHz	41 dBm for 10 MHz, 44 dBm for 20 MHz	46 dBm for 10 MHz, 49 dBm for 20 MHz	46 dBm for 10 MHz, 49 dBm for 20 MHz
User terminal (UT) power class	21 dBm	24 dBm	24 dBm	24 dBm
Carrier frequency (CF) for evaluation (representative of IMT bands)	3.4 GHz	2.5 GHz	2 GHz	800 MHz

Conclusions

LTE is the next generation OFDMA-based technology of choice for most 3GPP and 3GPP2 operators today, with over 100 operators already committed to deploying LTE starting in 2010. However, often overlooked is the opportunity to deploy LTE in unpaired spectrum. In this paper, we explored TD-LTE global momentum, differences to FDD, frame structure, system design and provided a sample result of its performance based on IMT-A channel model. The test covered additional TDD features such as UE specific reference symbol based beam forming and the performance for various workloads and DL/UL configurations.

Clearly, TD-LTE was developed to take advantage of the technical advancements as well as numerous similarities with TD-SCDMA which could enhance the LTE ecosystem. This innovation is now proving successful as TD-LTE is offering several operators in Europe, Asia, the Middle East, Africa and the Americas a flexible opportunity to adjust their business plans and deploy the leading next generation networks.

With the envisaged throughput and latency targets and its emphasis on simplicity, spectrum flexibility, uplink/downlink flexibility, added capacity, and lower cost per bit, TD-LTE is destined to provide many benefits. Among these are a greatly improved user experience, exciting new revenue generating mobile services, and a strong and viable option for mobile broadband technology in the next decade for both developed and emerging markets. Our *Applications for TD-LTE* solution paper addresses the question several traditional FDD operators are asking –"What applications can I deploy on my TD-LTE network? – and we will provide additional insight into our TD-LTE as more possibilities are opened.

Motorola is a global leader in 4G technologies and is delivering best-in-class LTE solutions by leveraging its extensive expertise in mobile broadband innovation, including OFDM technologies (WiMAX), cellular networking (EVDOrA, HSxPA), IMS ecosystem, collapsed IP architecture, standards development and implementation and comprehensive services.

For more information on LTE, please talk to your Motorola representative.

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Note – 3GPP documents may be downloaded from ftp://ftp.3gpp.org

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